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On Imposed 3-D Disturbances on Bluff-Body Near Wake Flows

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PROJECT ABSTRACT

Goals:

We wish to achieve a better understanding of the underlying physical mechanisms that make bluff body flows expected to be characterized by two-dimensionality exhibit three-dimensional effects. Further we hope to be able to associate these effects which are characterized by vortex splitting and vortex looping to various properties of the flow such as drag, base pressure, shedding frequency, wake formation length and possibly to the global instability of the flow.

Objectives:

In order to attain our goal of understanding the three-dimensionality in the near wake region, we examine the flow around two bluff bodies with mild three-dimensional disturbances imposed by their geometry, a wavy-trailing edge blunt base section body (BB) and a circular cylinder with periodic splitter plates affixed (CC) respectively.

Approach:

The approach of the research is primarily experimental. Fluctuating velocities and pressures are measured in low turbulence wind tunnels at both institutions using hot-wire anemometry and pressure transducers mounted inside the models respectively. Flow visualization has been carried out in a water channel using electrolytic precipitation technique as well as in the wind tunnels with smoke.

Tasks Completed:

For BB models with periodic spanwise disturbances:

- Spectra of velocity and pressure signals were measured as well as base pressures and spanwise pressure correlations.

- Successful flow visualization has lead to the observation of varicose and oblique modes of shedding.
- For future experiments a new model was designed and built so as to permit geometrical modifications and high frequency pressure measurements to be made and an existing traverse gear was comprehensively refurbished.

For the CC models with periodic splitter plates:

- Mean pressures were measured as well as spanwise base pressures.
- Formation lengths were measured at peaks and valleys and correlated to base pressure measurements and drag calculations.
- Smoke and naphthalene flow visualization each provided the details of the three-dimensional character of the near wake flow.
- A new CC model was designed to permit the simultaneous measurement of eight pressure signals along the span in the base region.

Results:

Results of the experimental investigation of the effects of imposed three - dimensionality on the flow characteristics about both bluff bodies have indicated that many similarities exist for the two models as well as some differences which have yet to be fully understood.

We find that for both bodies the drag is reduced as the steepness of the geometrically imposed disturbances is increased. For the BB model the drag is found to be higher at the valleys than at the peaks whereas for the CC model the opposite is observed. In both cases however the drag at the valley is still lower than that measured for an equivalent two-dimensional body for the BB model or for an equivalent straight splitter plate for the CC model.

Velocity spectra at the peaks show the presence of two shedding requencies, the strength of the lower one falling as we move towards the valley. These results indicate that the strongest three-dimensional effects are present at the peaks. Flow visualization for the BB body confirmed the above, with vortex splitting occurring at a peak quite regularly. Flow visualization for the CC body indicated strong flow movement from the valleys to the peaks and support the evidence found for the BB body. In both cases base pressure signals indicated large instantaneous spanwise pressure gradients are present.

The formation lengths for both models are larger at the valleys than at the peaks. In the case of the CC model the the formation length appears to reach a maximum at a point where the drag reaches a minimum i. e., the point at which the valley length is equal to the length of the straight splitter plate for which drag is minimum.

Accomplishments:

1. Observed two modes of vortex shedding and two shedding frequencies at peaks.
2. Demonstrated that three-dimensional disturbances increase base pressure.
3. Measured formation lengths are larger at the valleys than at the peaks.

PUBLICATIONS FROM ONR SPONSORED WORK - FY90/91
Professor Albin A. Szewczyk
December 1991

90-C Szewczyk, A. A., Bearman, P. W., and Tombazis, N., Effects of Three-Dimensional Disturbances Generated by Splitter Plates on the Near-Wake Flow behind a Circular Cylinder, Bull. APS, 35,10 (1990) 2257.

91-C Szewczyk, A. A., Bearman, P. W., and Tombazis, N., Effect of Imposed Three-Dimensionality on Flows Past Bluff Bodies, Bull. APS 36,10 (1991) 2656.

91-C Szewczyk, A. A., Bearman, P. W., Effects of 3-D Imposed Disturbances on Bluff-Body Near Wake Flows, ONR Workshop, Mar. 1991.

91-PI Pearson L. and Szewczyk A. A., An Experimental Analysis of the Effects of Imposed Three-Dimensionality on the Near Wake of a Circular Cylinder, Submitted to ASME International Symposium of Flow-Induced Vibrations, WAM, 1992.

91-R Borg, J., Unsteady Base Pressure Measurements on a Bluff Body With Imposed Three-Dimensionality, M. S. Thesis, U. of Notre Dame.1991-92.

91-R Pearson, L., On Imposed Three-Dimensional Disturbances in the Near Wake of a Circular Cylinder, M. S. Thesis,U. of Notre Dame, 1991-92.

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a. Number of Papers Submitted to Refereed Journal but not yet published: 0

b. Number of Papers Published in Refereed Journals: 0
(list attached)

c. Number of Books or Chapters Submitted but not yet Published: 0

d. Number of Books or Chapters Published: 0 (list attached)

e. Number of Printed Technical Reports & Non-Refereed Papers: 1
(list attached)

f. Number of Patents Filed: 0

g. Number of Patents Granted: 0 (list attached)

h. Number of Invited Presentations at Workshops or Prof. Society Meetings: 0

i. Number of Presentations at Workshops or Prof. Society Meetings: 3

j. Honors/Awards/Prizes for Contract/Grant Employees:
(list attached, this might include Scientific Soc. Awards/ Offices, Promotions/Faculty Awards/Offices, etc.)

k. Total number of Graduate Students and Post-Docs Supported at least 25% this year on this contract/grant:

Grad Students 3 and Post-Docs 0 including
Grad Student Female 1 and Post-Docs Female 0
Grad Student Minority 0 and Post-Doc Minority 0

Minorities include Blacks, Aleuts, AmIndians, Hispanics, etc.
NB: Asians are not considered an under-represented or minority group in science and engineering.

Enclosure (3)